



Projections of Climate Change Impacts on Hurricane-Induced Waves and Coastal Erosion in a Mid-Atlantic Region of the United States

Reza Marsooli

Mohammad Jamous

Jon Miller

Dept. of Civil, Environmental, and Ocean Eng.
Stevens Institute of Technology, Hoboken, NJ

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Storm Surges, and Coastal Hazards

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Introduction

New Jersey Barrier Islands

- The islands accommodate tens of thousands of residents and drive state's tourism industry.
- They protect the mainland against waves from the Atlantic Ocean.
- Sandy beaches and dunes on these islands are the main lines of defense against extreme sea levels.



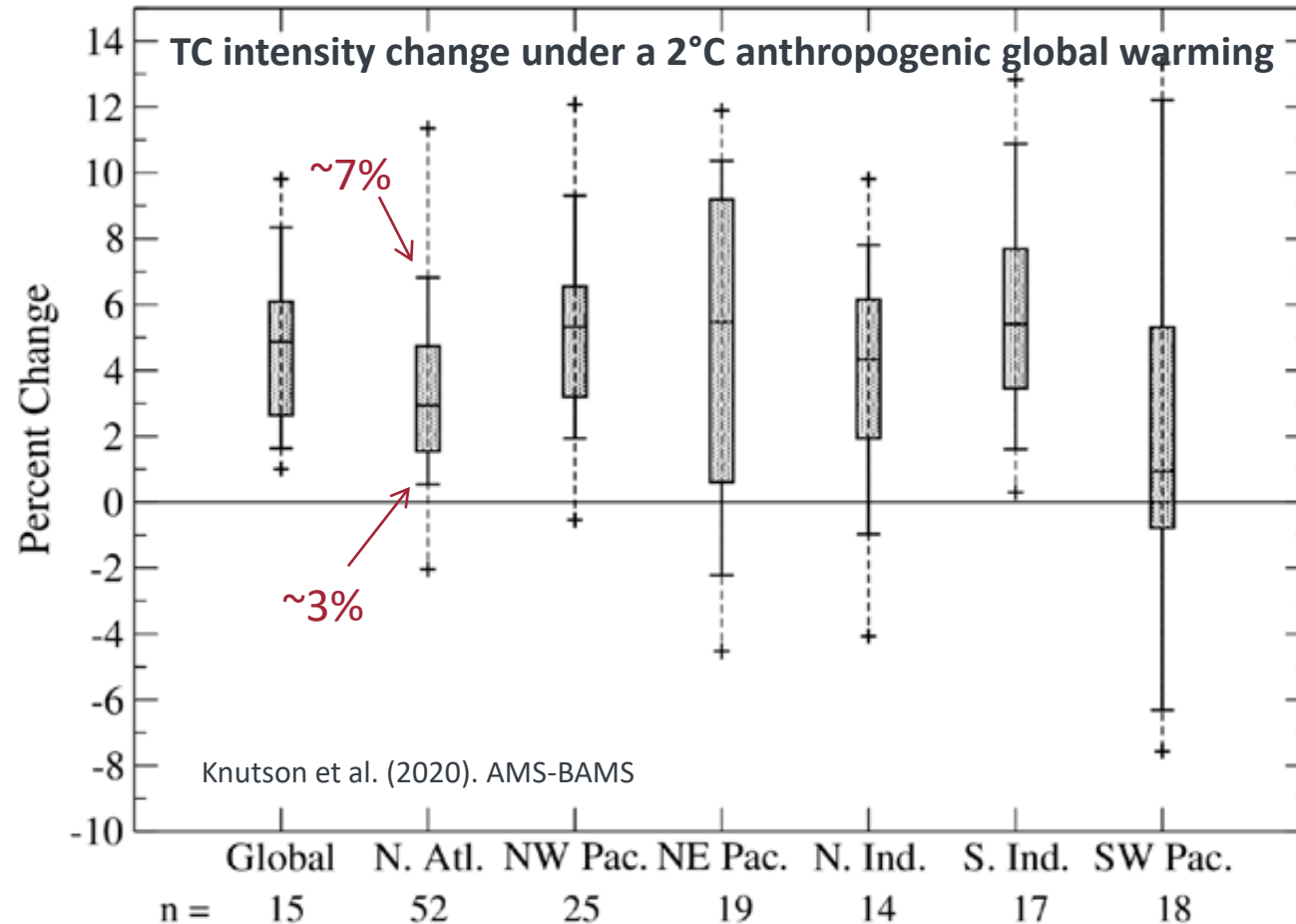
Coastal Erosion Hazards

- Large waves generated by tropical cyclones are among the drivers of the historical extreme erosion events.



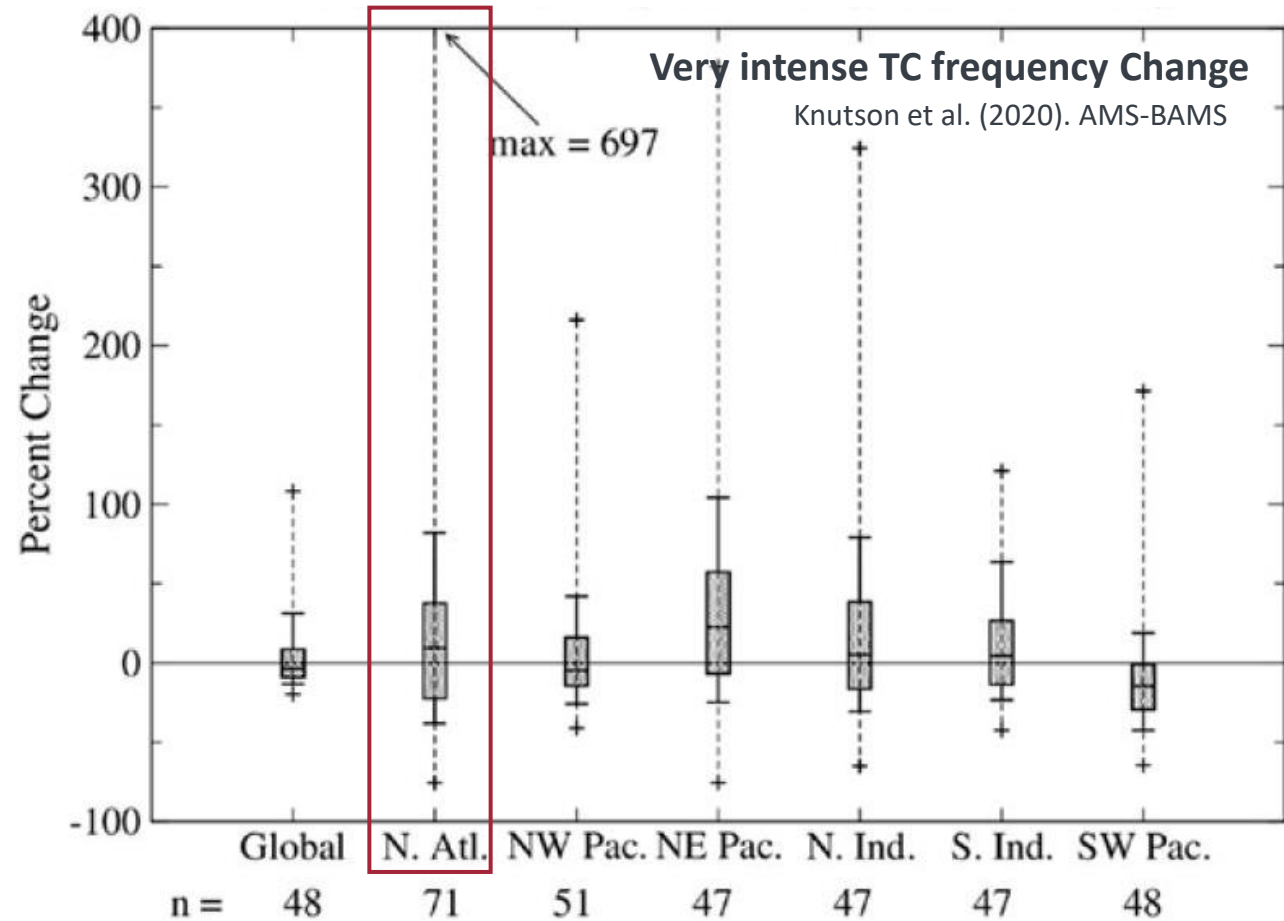
Climate Change Impacts

- Changes in the intensity of tropical cyclones (TCs) will influence wave and erosion hazards.



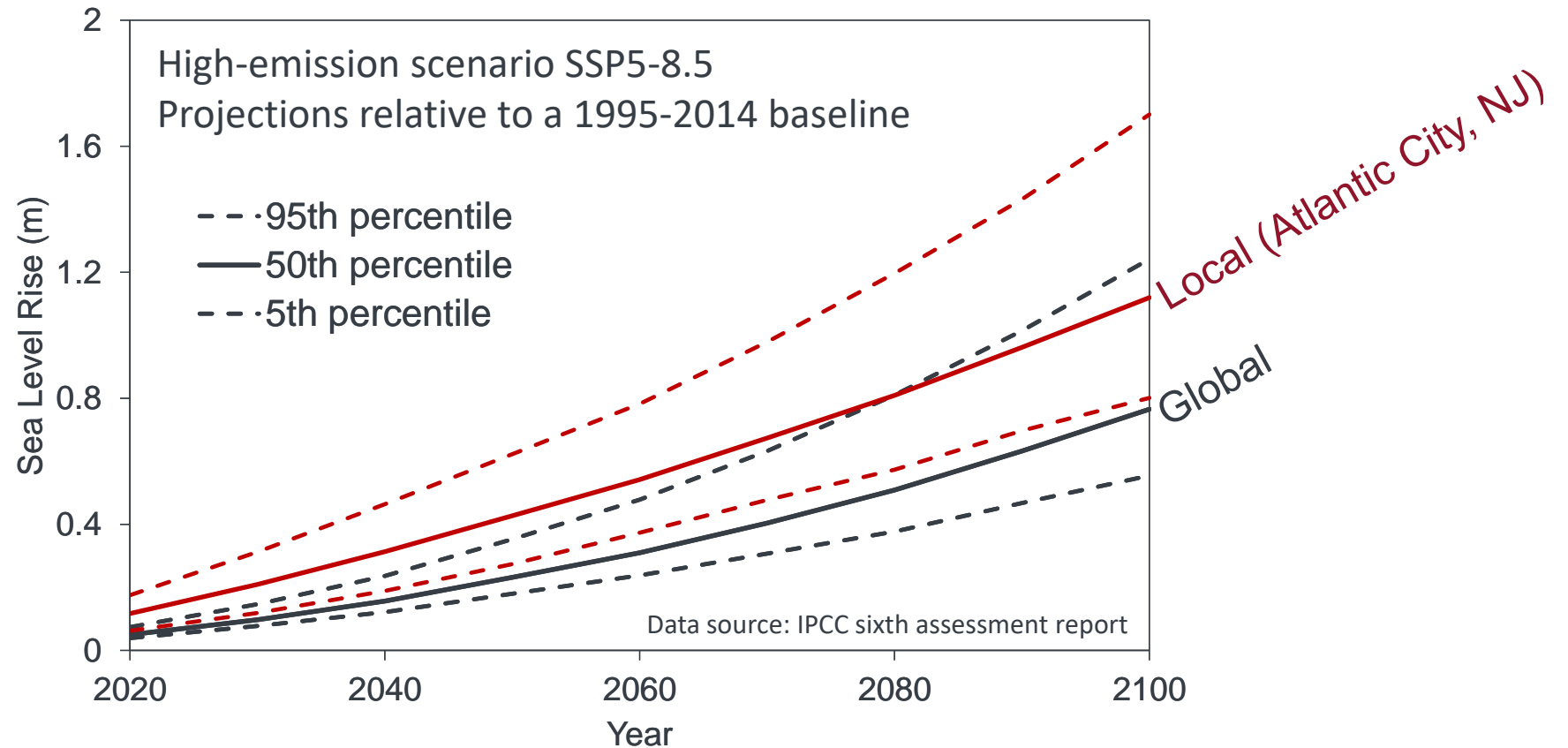
Climate Change Impacts

- Wave and erosion hazards will also be influenced by changes in the frequency of TCs.



Climate Change Impacts

- Wave hazards in coastal waters can be also influenced by sea level rise (SLR).



Goal and Objectives

The goal is to

- quantify climate change impact on extreme wave hazards along the barrier islands of New Jersey.

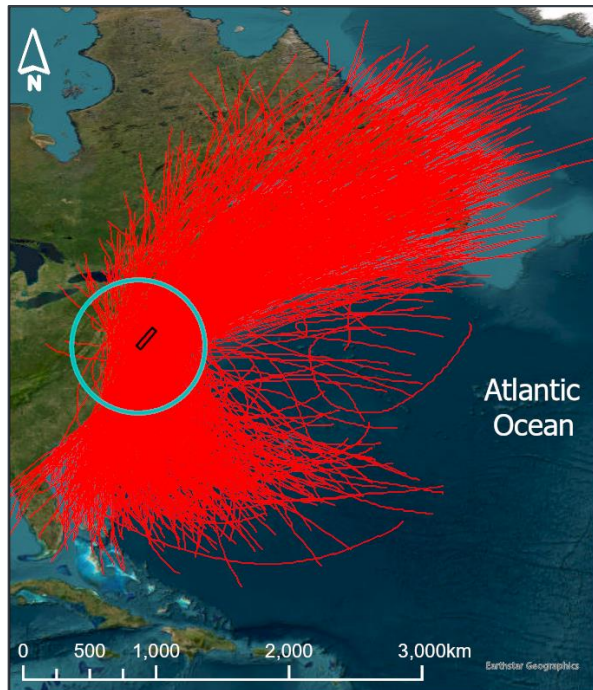
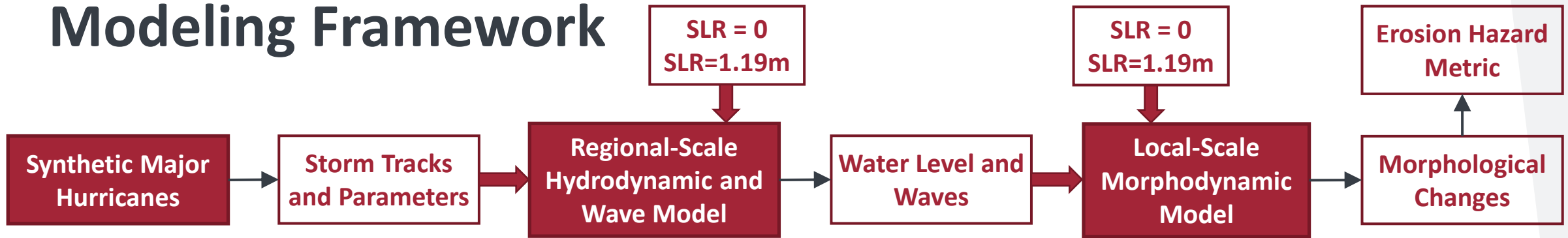
The objectives are to quantify

- changes to wave hazards due to major hurricanes from a historical period in the late 20th century to a future period in the late 21st century under a high-emission scenario,
- how the extreme erosion hazards to beach-dune systems would respond to changes in hurricane-induced waves, and
- the effects of sea level rise on both hurricane-induced wave and coastal erosion hazards.

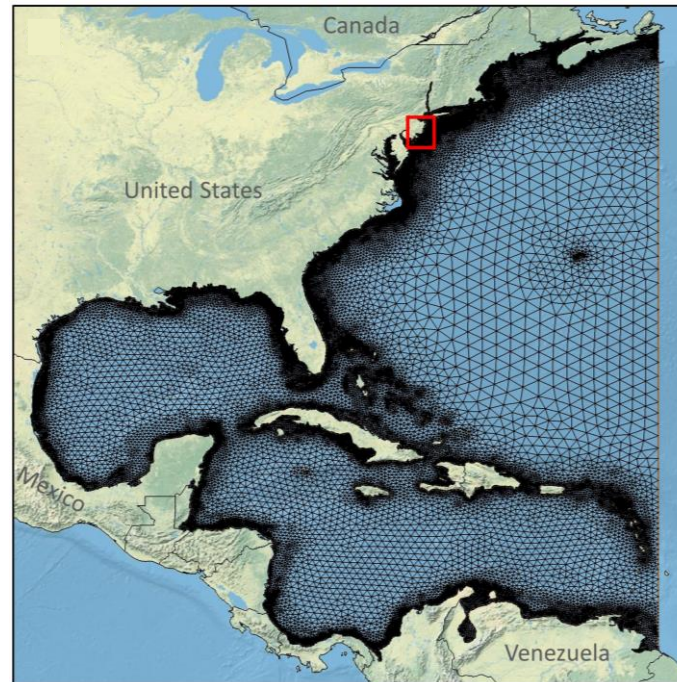


Methods

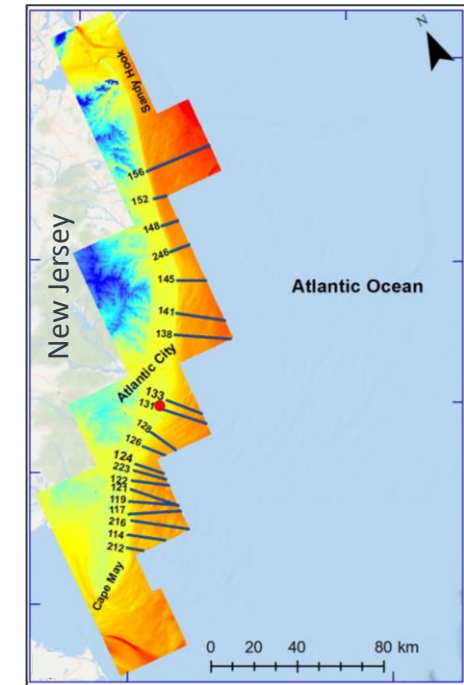
Modeling Framework



Cat 3-5 hurricanes
1980-2000 and 2080-2100 (RCP8.5)
Data source: Marsooli and Lin 2020, Climatic Change.

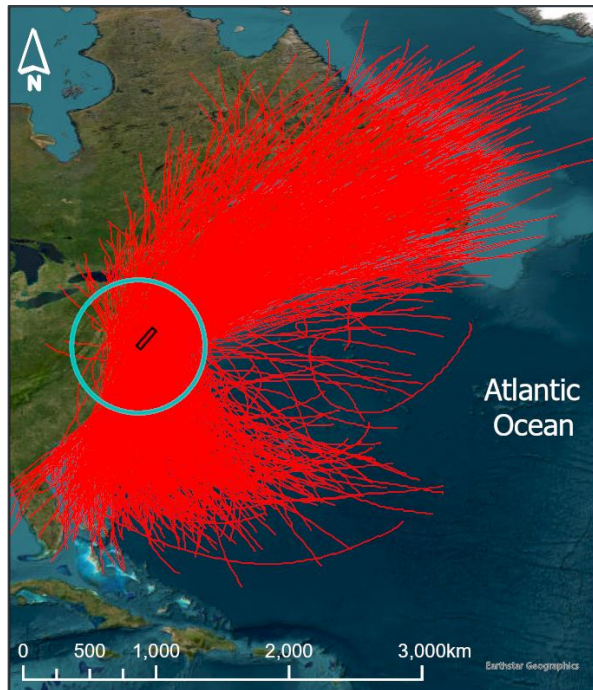
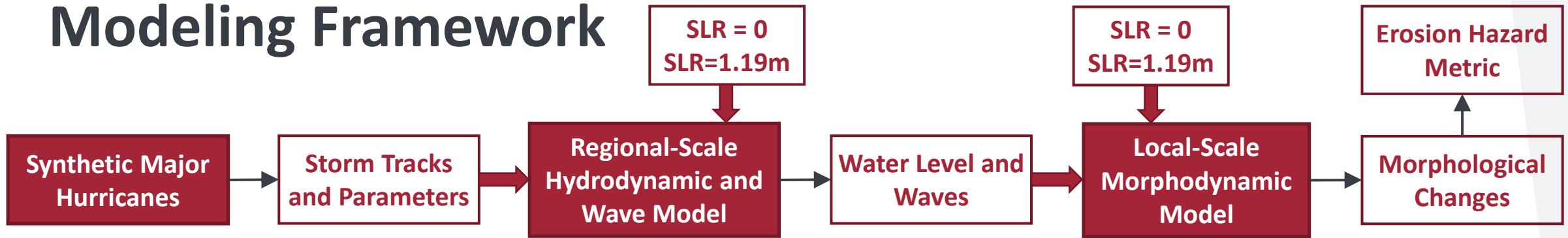


ADCIRC+SWAN model
Marsooli et al. 2021. frontier: Climate Impact on Coastal Zones

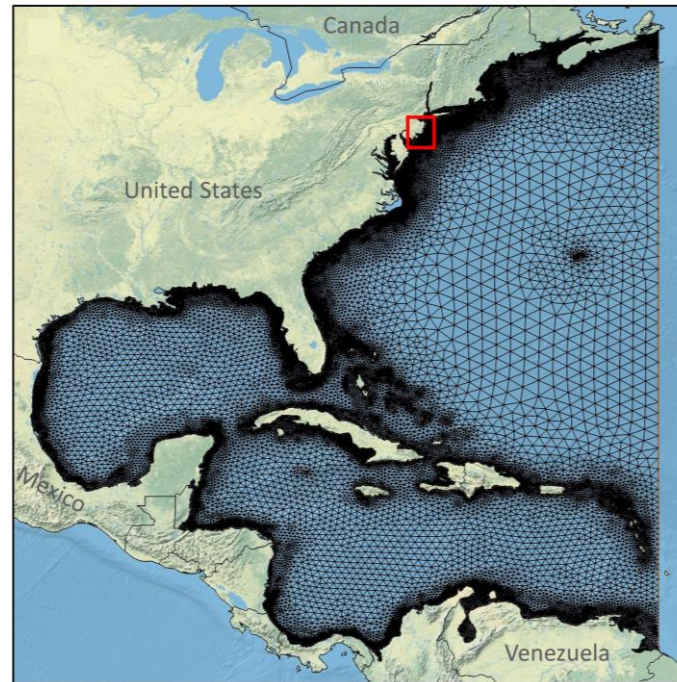


XBeach model
Jamous et al. 2023. Environmental Modelling & Software

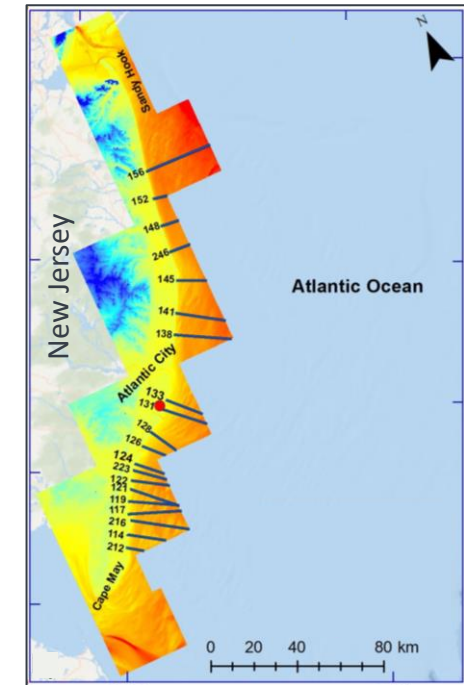
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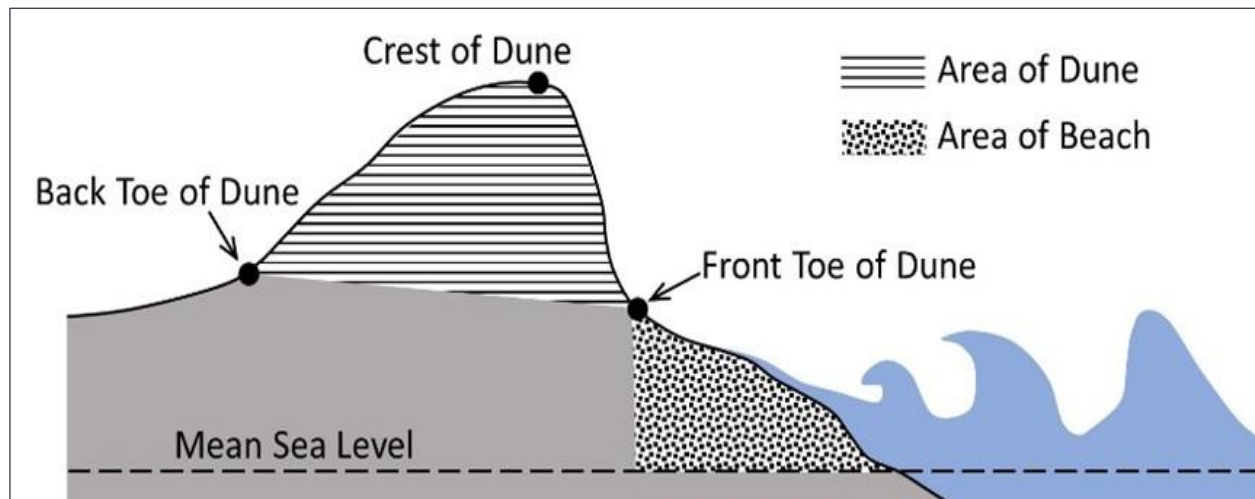
Erosion Hazard Metric

- Total Eroded Volume (TEV)

$$\text{TEV} = 100 \times \frac{V_E}{V}$$

V_E : eroded volume of beach-dune

V : total initial beach-dune volume

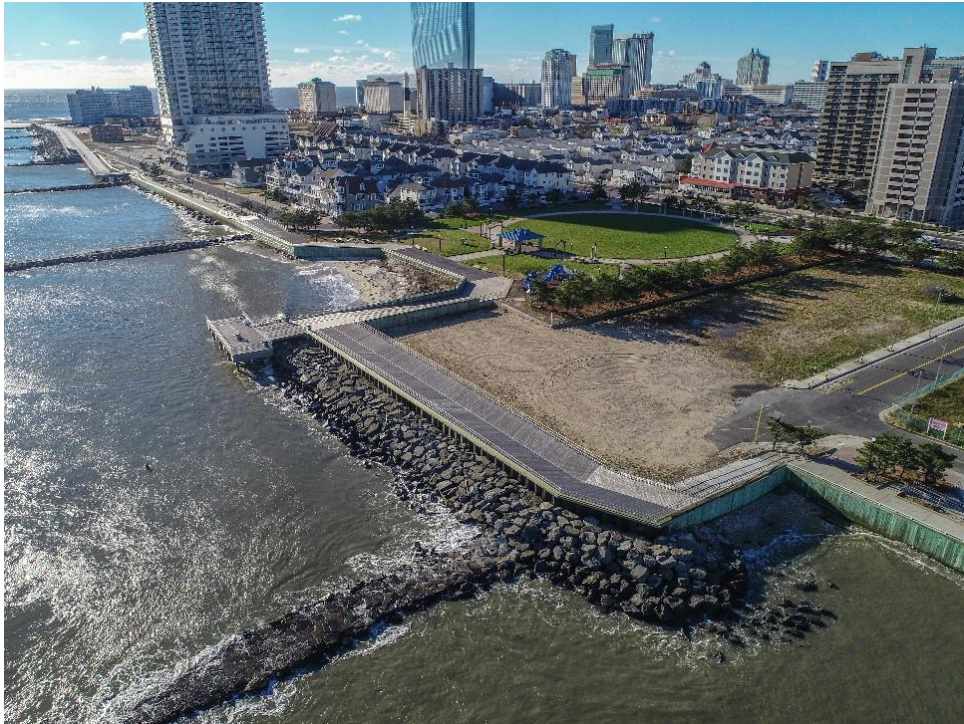


Classification of storm-induced damage to beaches and dunes (Lemke and Miller 2021)

Damage Class	Definition
Major	Volume Change >40%
Moderate	Volume Change 5–40%
Minor	Volume Change <5%

Method: Assumption

- We assume that present-day dunes will not migrate upland.

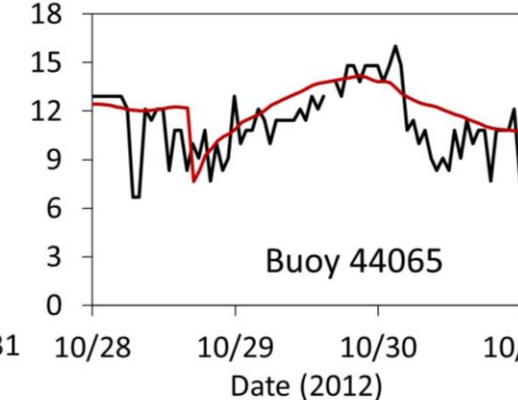
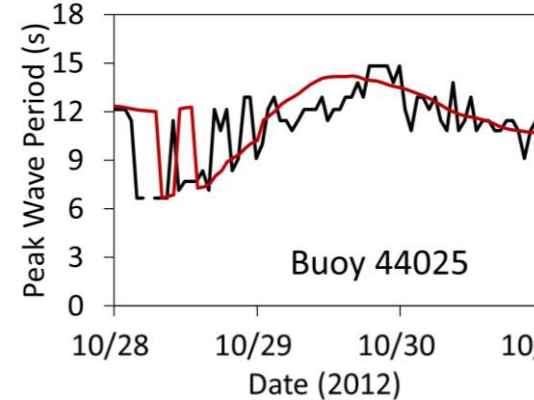
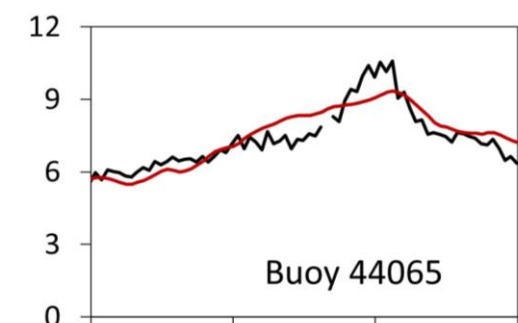
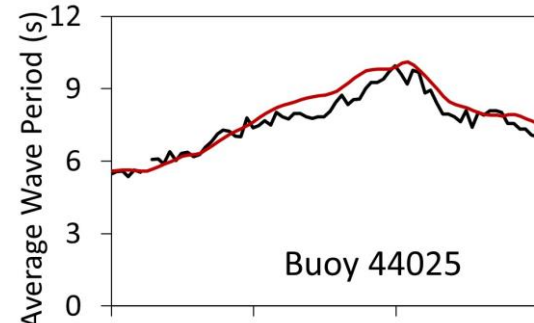
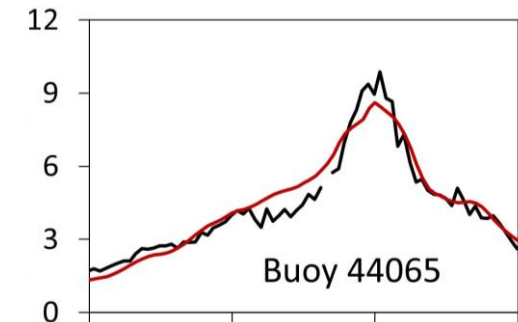
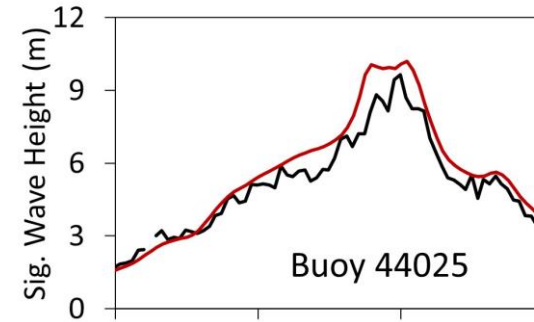
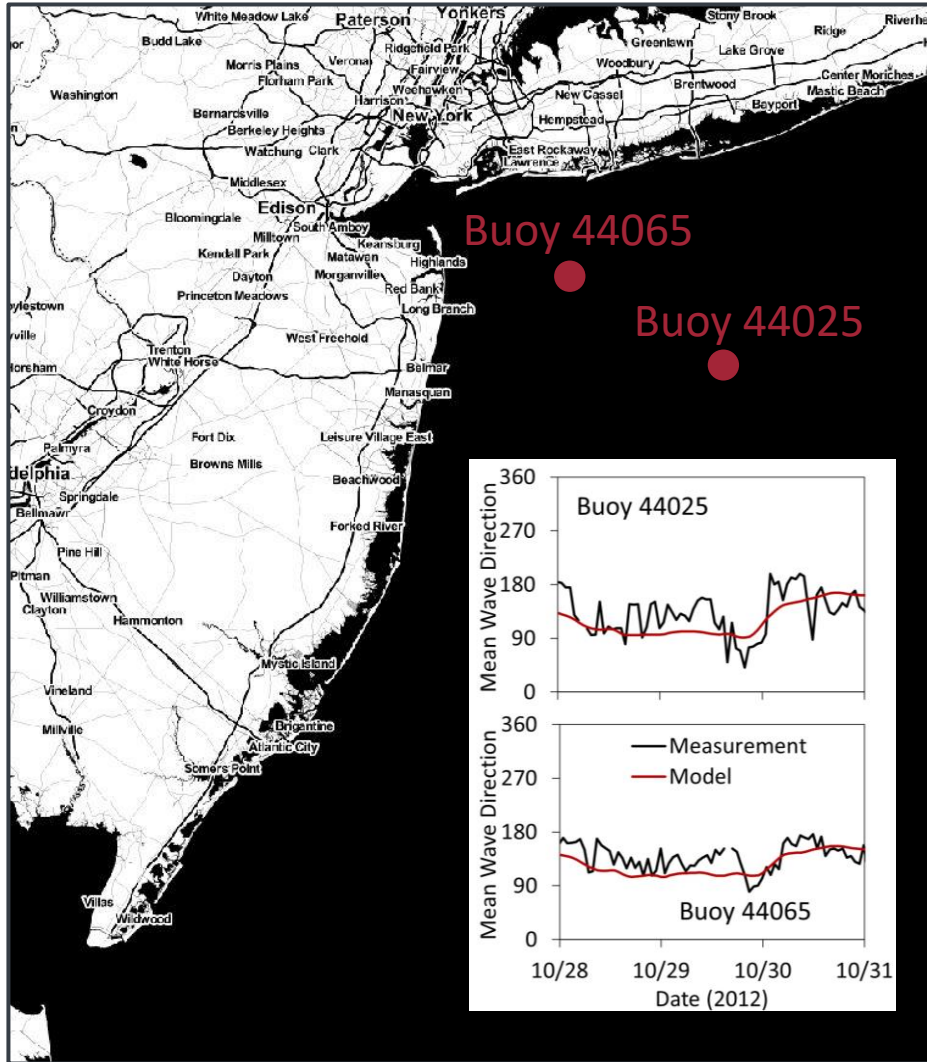


Photos from Philadelphia District, U.S. Army Corps of Engineers



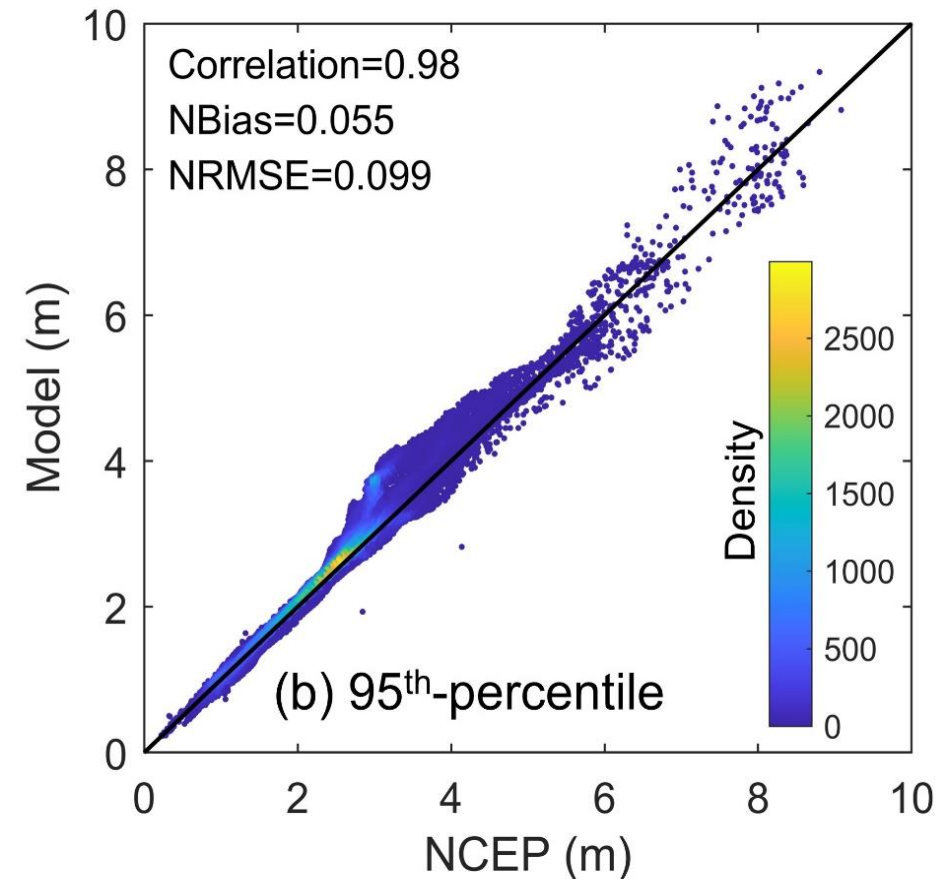
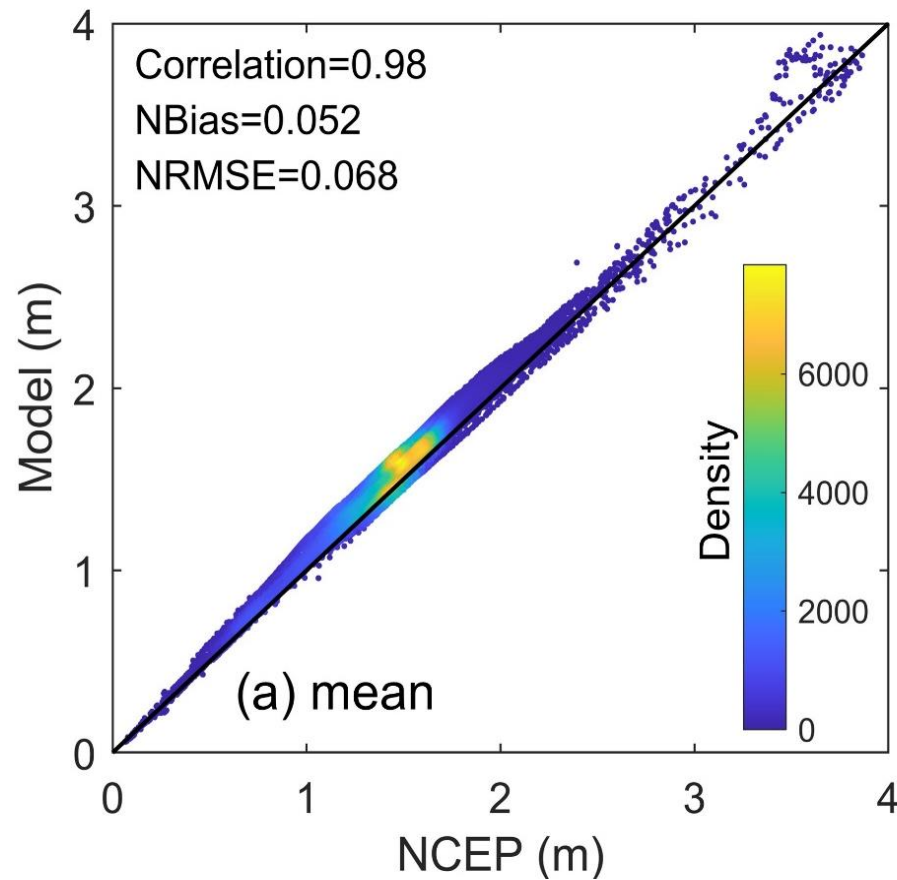
ADCIRC+SWAN Model Validation

Hurricane Sandy 2012



Synthetic Hurricane Validation

- Validation against NCEP-based synthetic hurricane dataset.



XBeach Model Calibration

Sensitivity analysis: 6 input parameters

Parameter	Description	Default	XBeach Range	Calibration Range	Sensitivity Range
<i>facua</i>	Calibration due to wave skewness and asymmetry.	0.1	0 – 1	0 - 0.4	0.05 - 0.25
wetslp	Critical avalanching slope underwater	0.3	0.1 – 1	0.1 – 1	0.25 – 0.7
gamma	Breaker Parameter	0.55	0.4 - 0.9	0.4 - 0.9	0.4 – 0.6
gammax	Maximum ratio wave height to water depth	2.0	0.4 - 5.0	0.4 - 5.0	1.0 – 3.0
alpha	Wave dissipation coefficient in Roelvink formulation	1.0	0.5 - 2.0	0.5 - 2.0	0.8 – 2.0
beta	Breaker slope coefficient in roller model	0.1	0.05 - 0.3	0.05 - 0.3	0.1 – 0.3



Environmental Modelling & Software

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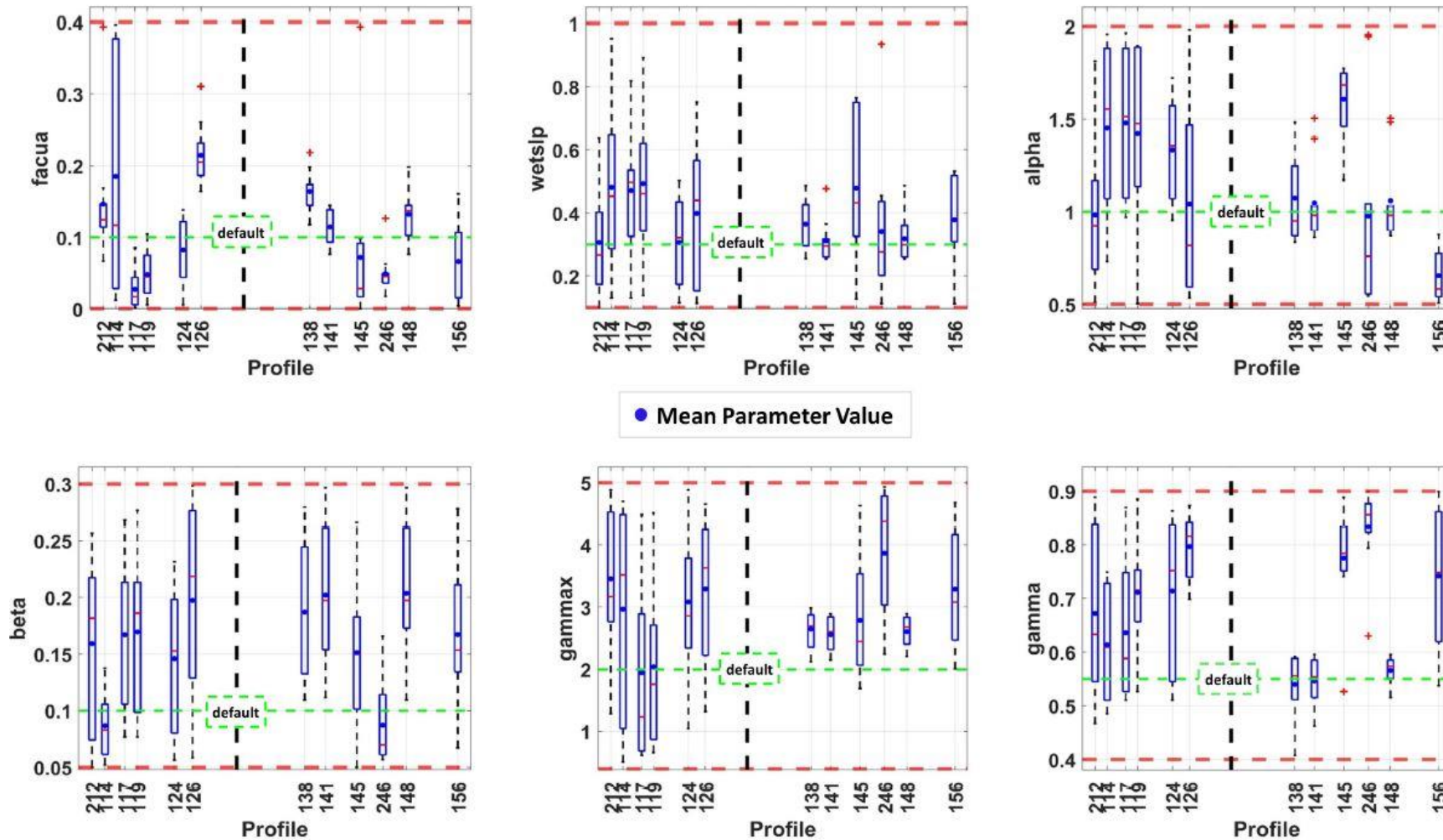
Position Paper

Global sensitivity and uncertainty analysis of a coastal morphodynamic model using Polynomial Chaos Expansions

[Mohammad Jamous](#), [Reza Marsooli](#)  , [Mahmoud Ayyad](#)

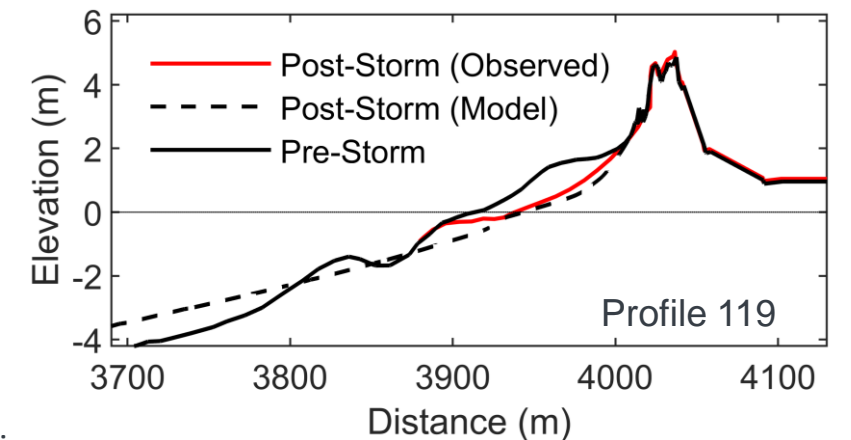
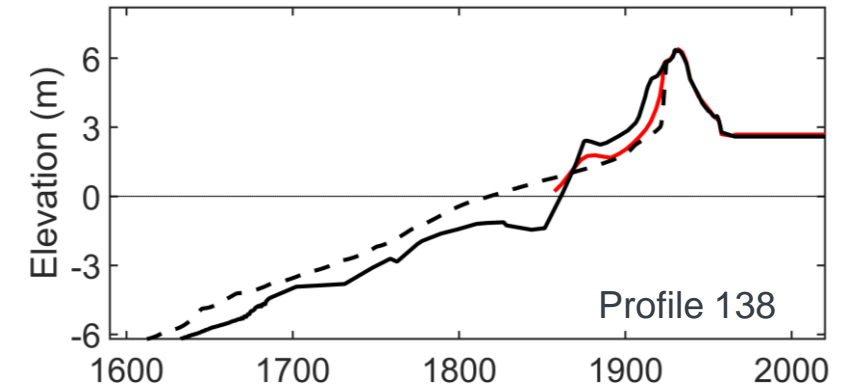
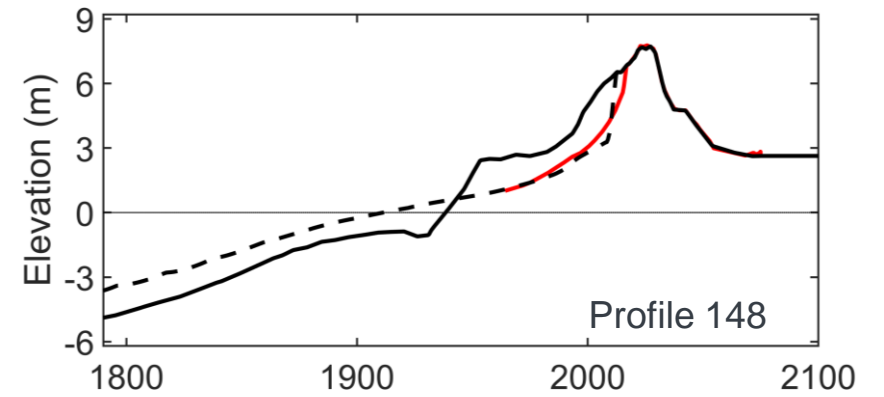
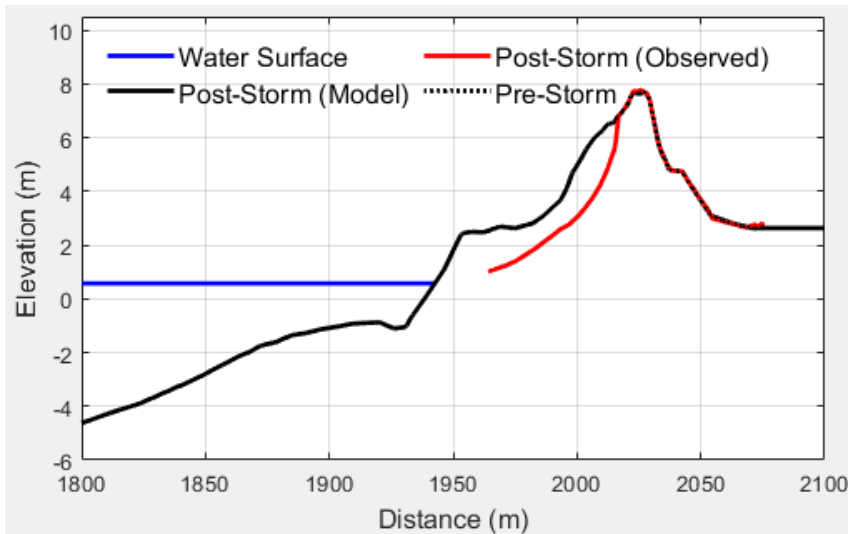
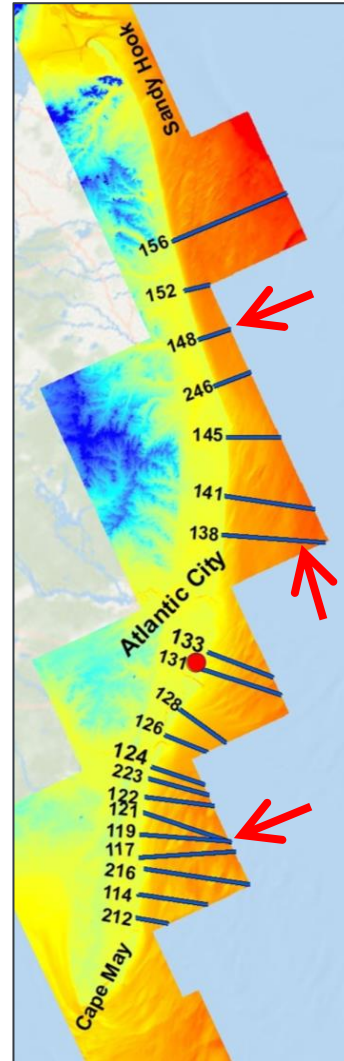
XBeach Model Calibration

Box plot of the parameters used in the 10 top simulations with the highest BSS scores



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XBeach Model Validation

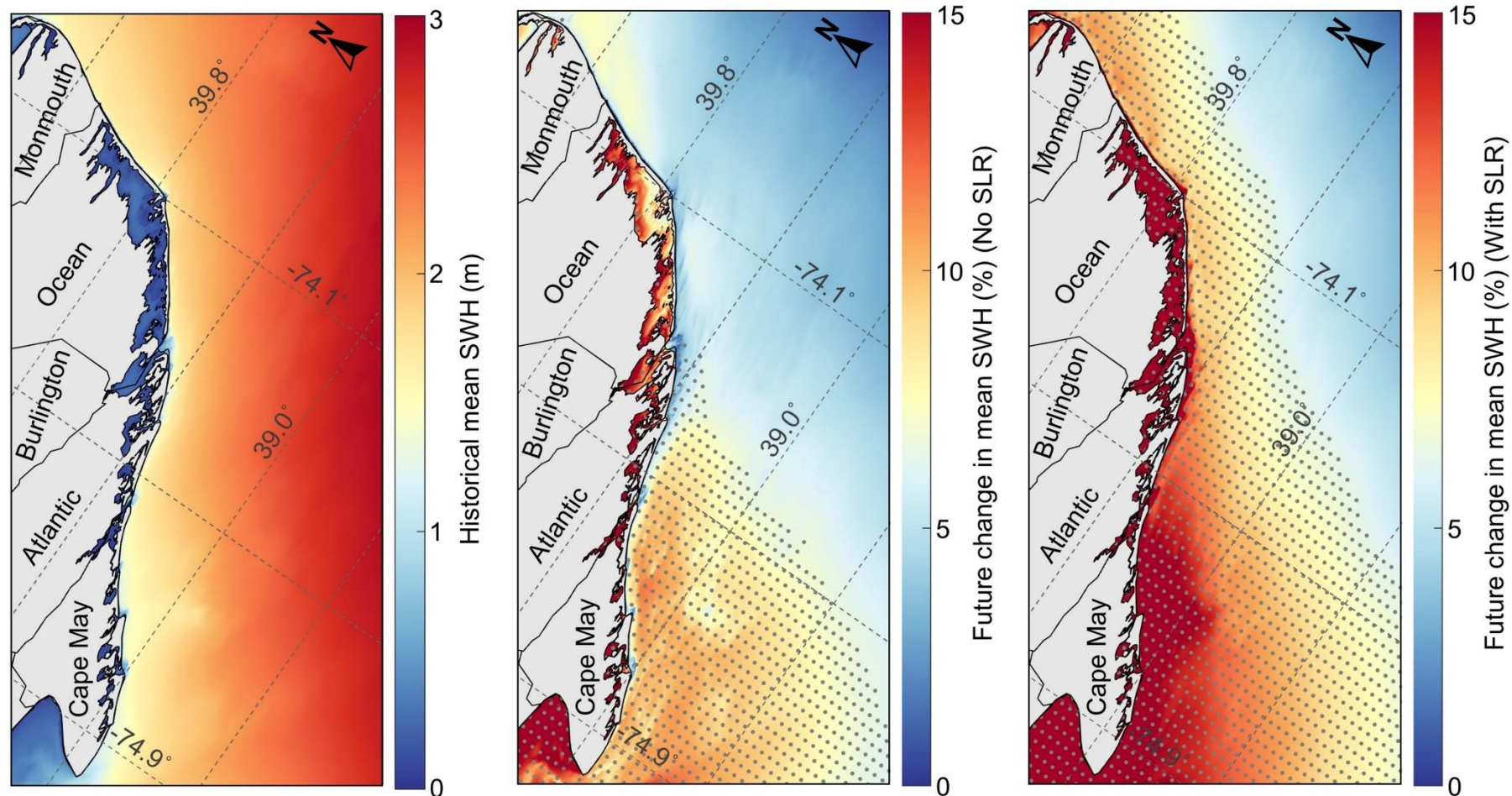


Pre- and post-storm measurements provided by the Coastal Research Center at Stockton University

Results

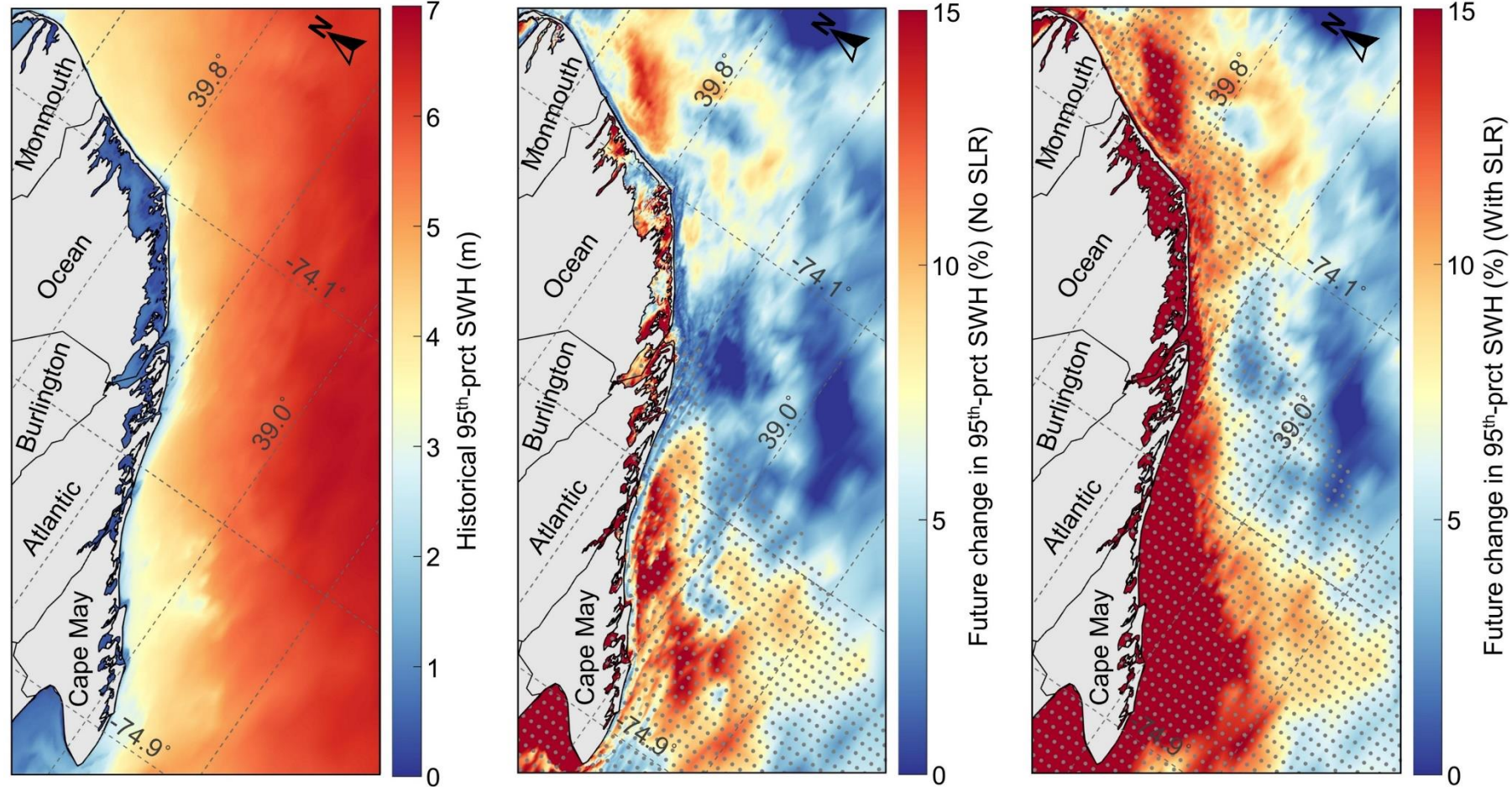
Projections of Future Changes: Wave Height

- The projected increases in the mean SWH exceed 15% when considering both SLR and hurricane climatology change.



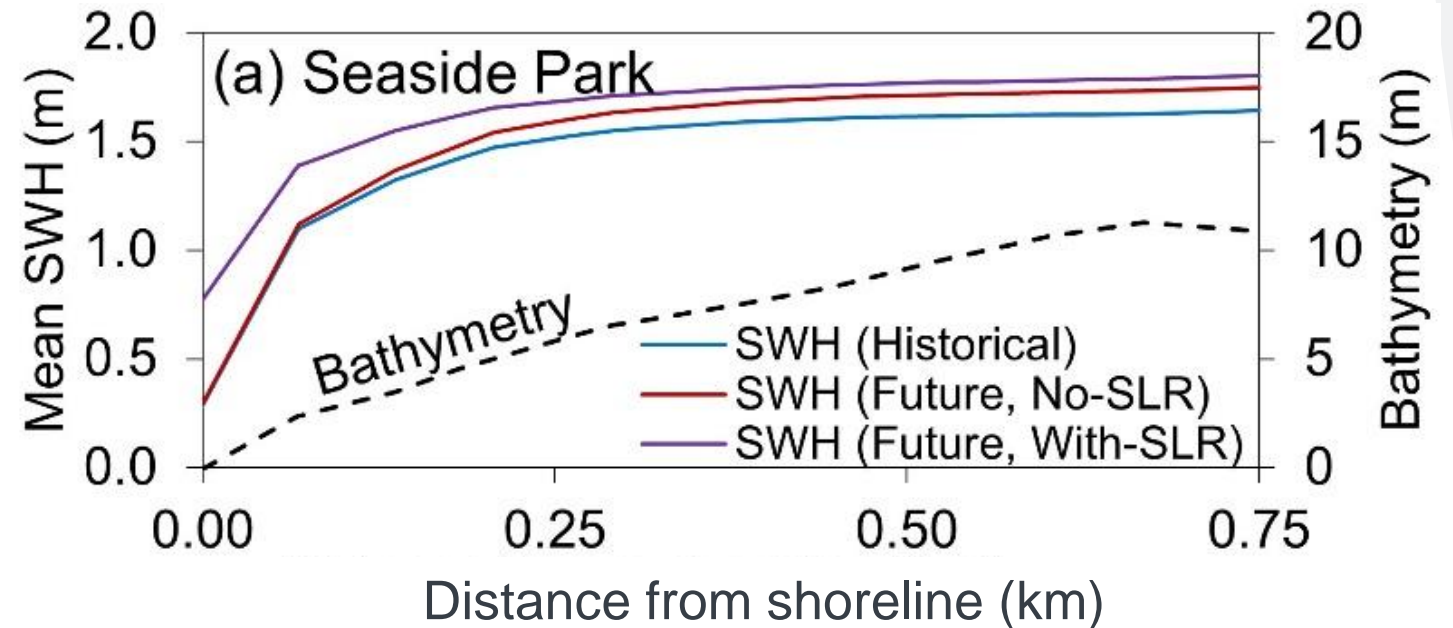
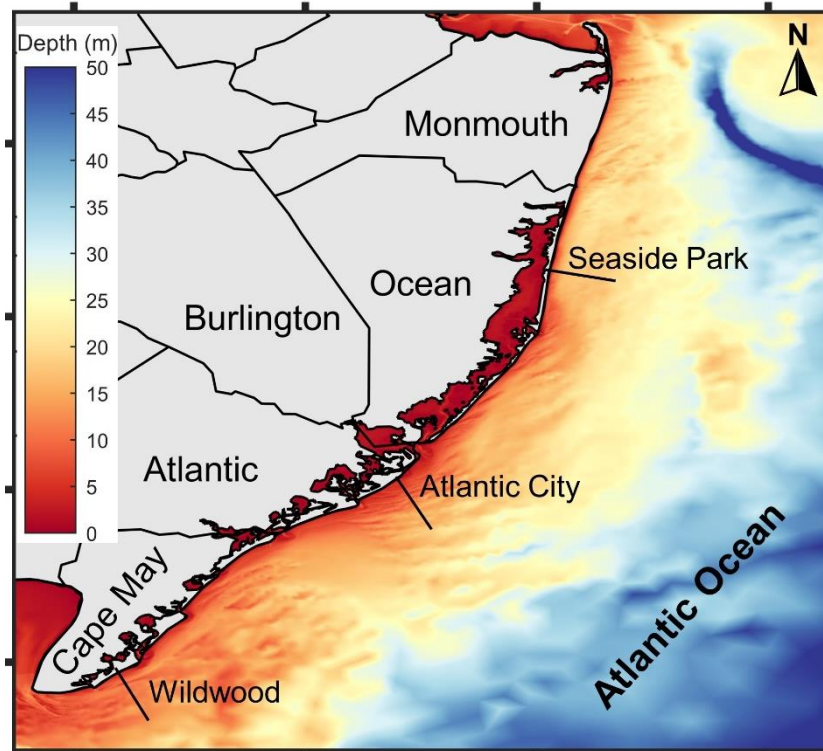
Projections of Future Changes: Wave Height

- Similar increasing patterns are projected for the 95th-percentile SWH but with a higher magnitude.

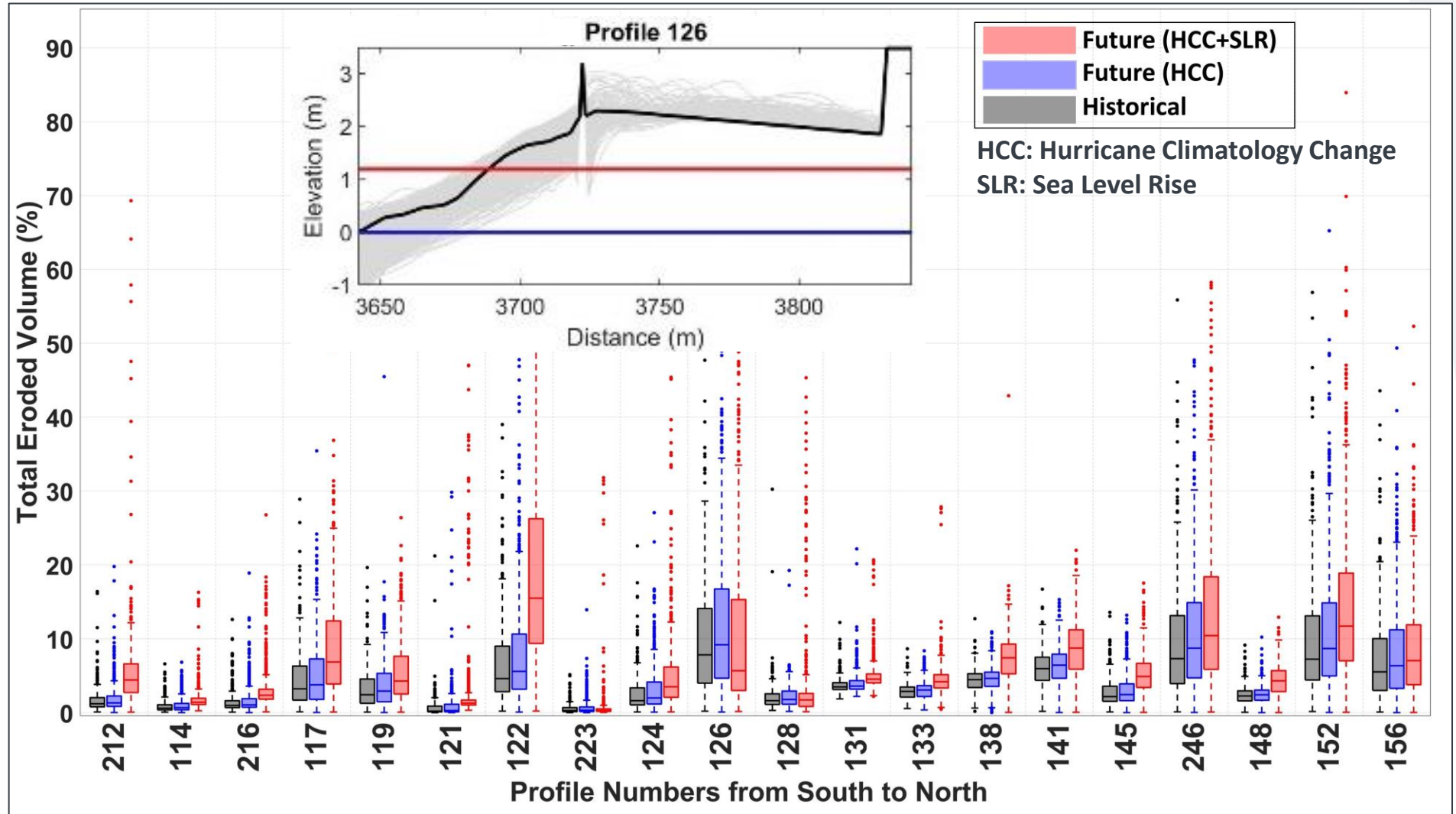
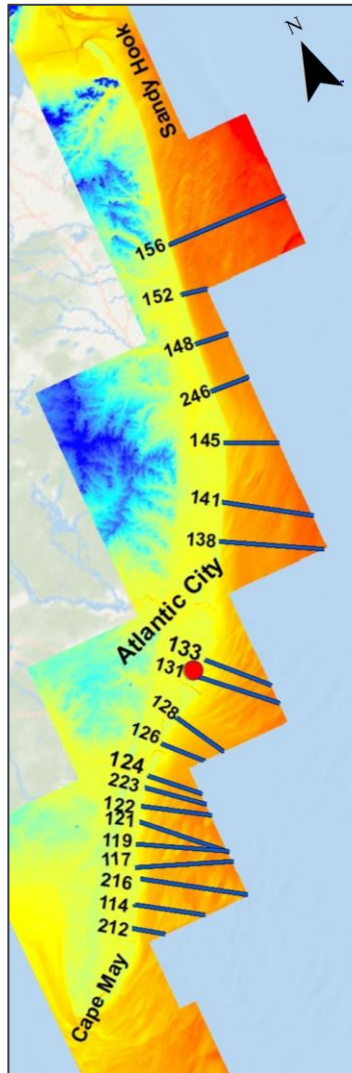


Projections of Future Changes: Wave Height

- While hurricane climate change is the main cause of increase in offshore wave height, SLR would result in substantial increases in wave heights in shallow waters.



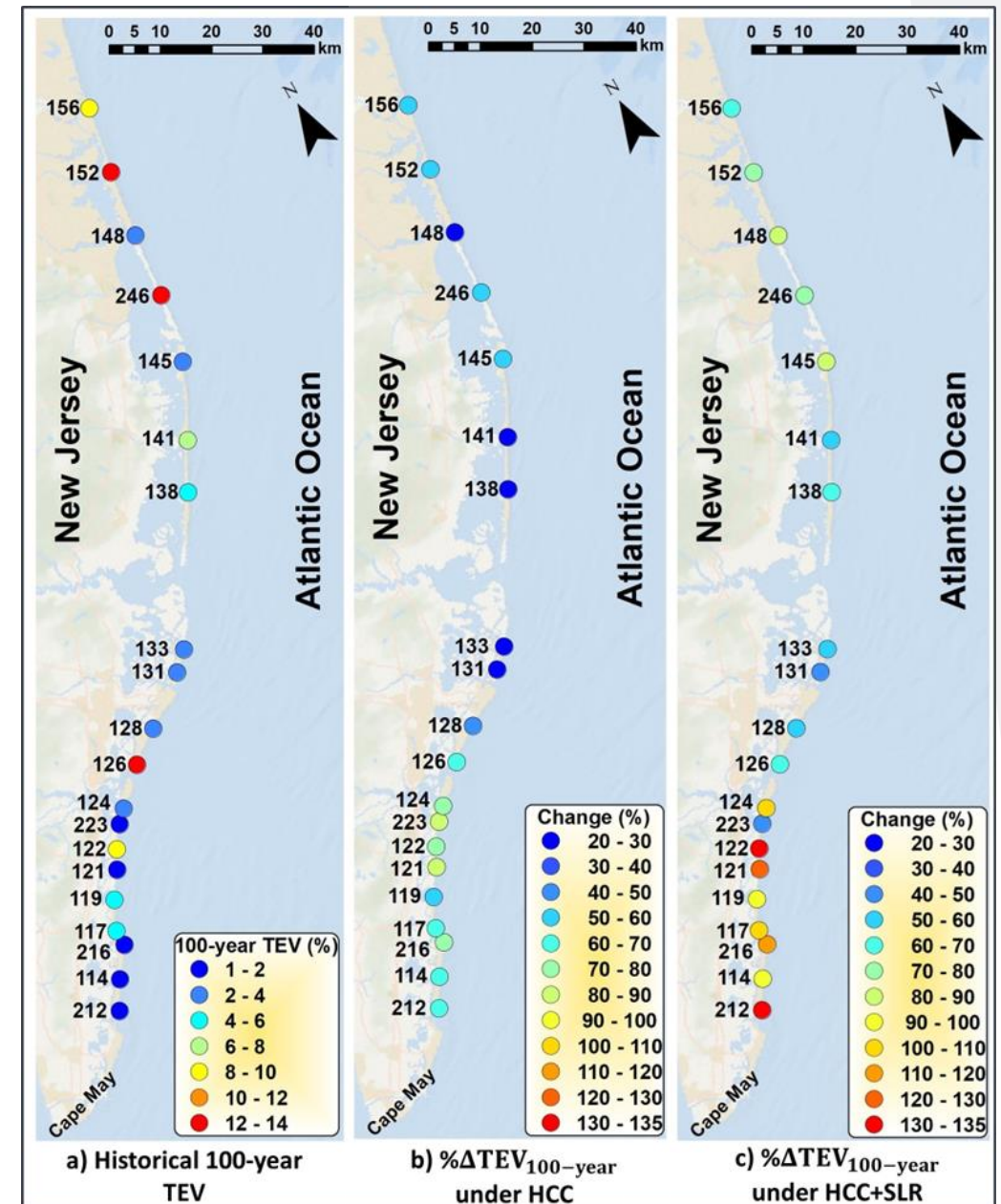
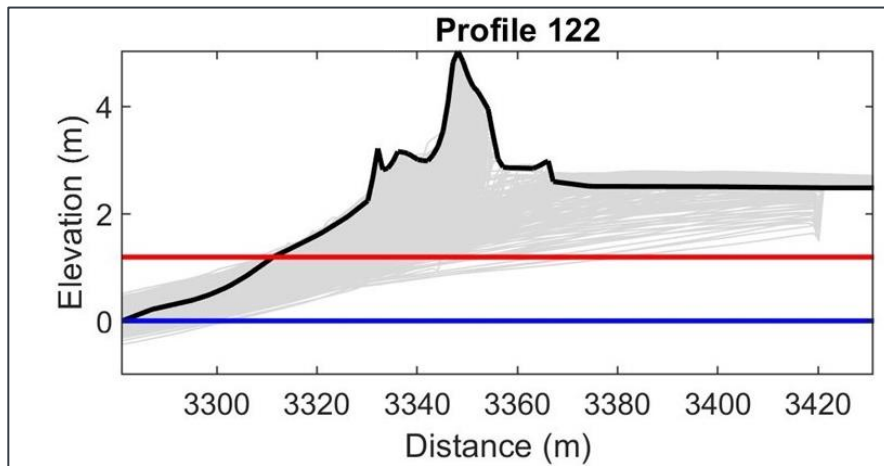
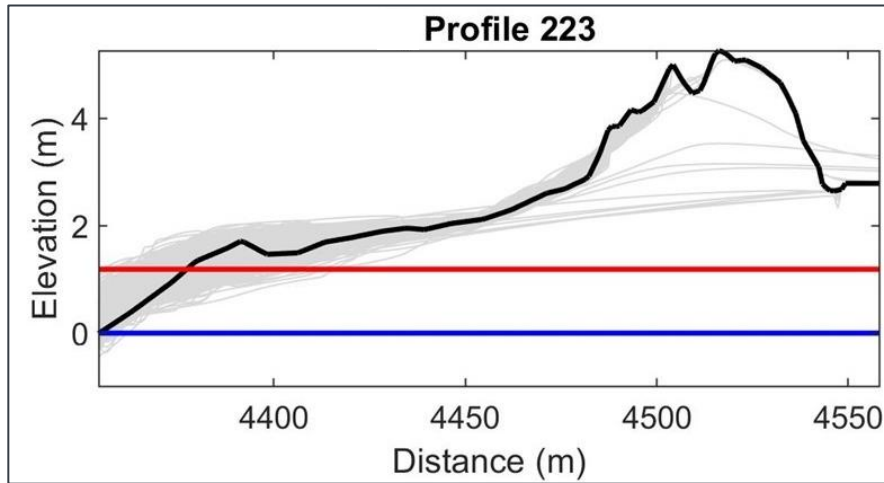
Projections of Future Changes: Coastal Erosion



Jamous et al. (2023). npj Climate and Atmospheric Science

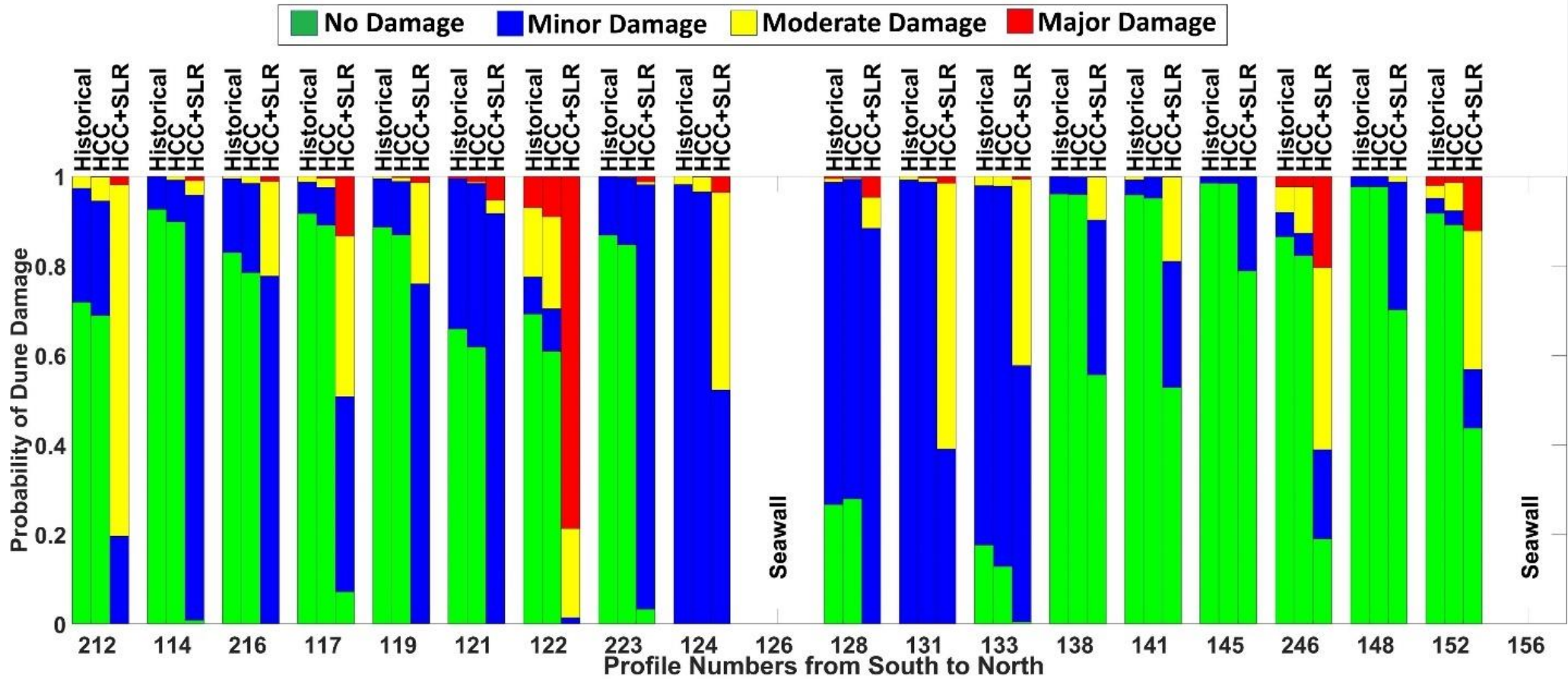
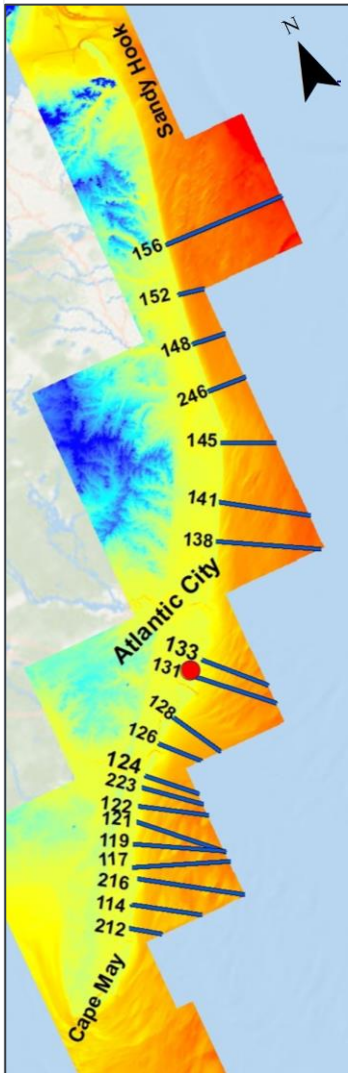
Projections of Future Changes: Coastal Erosion

Future Changes to 100-year TEV



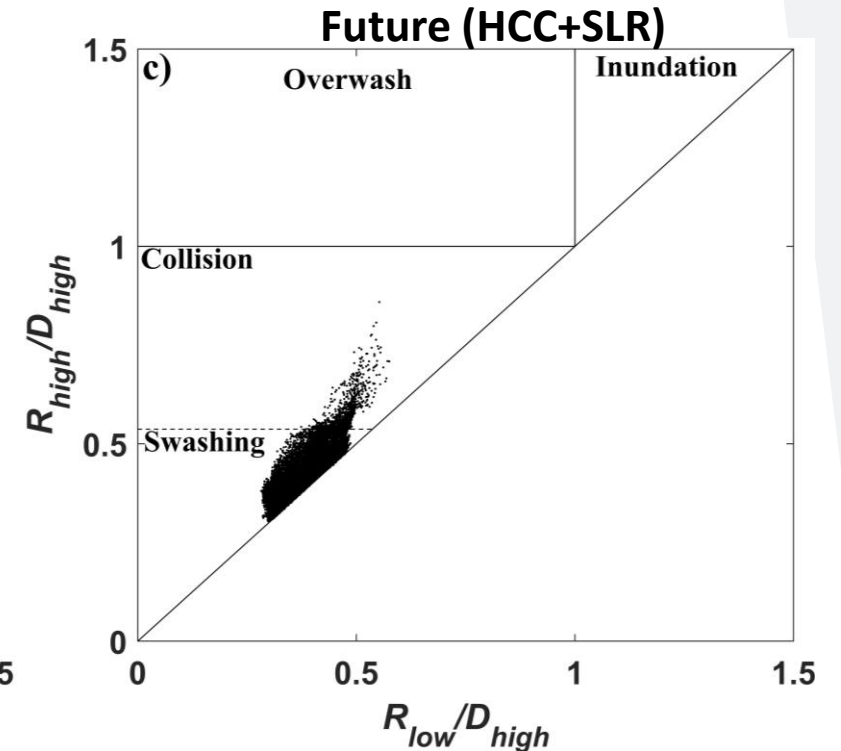
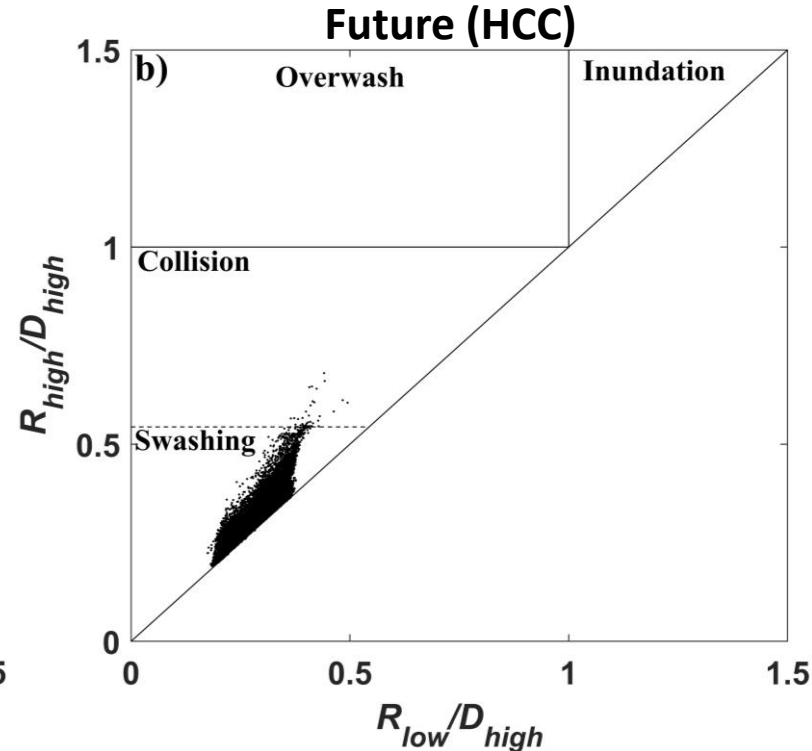
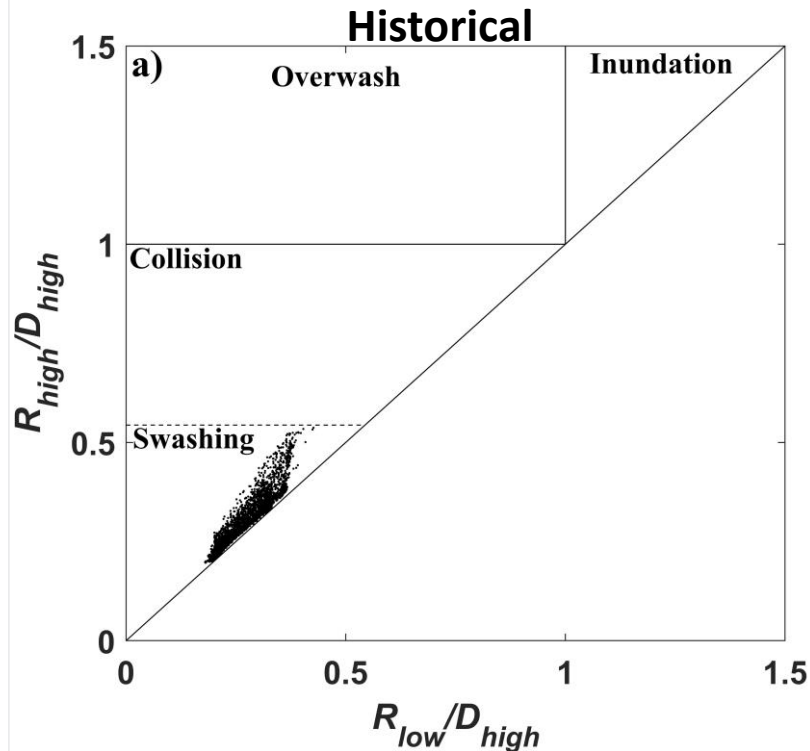
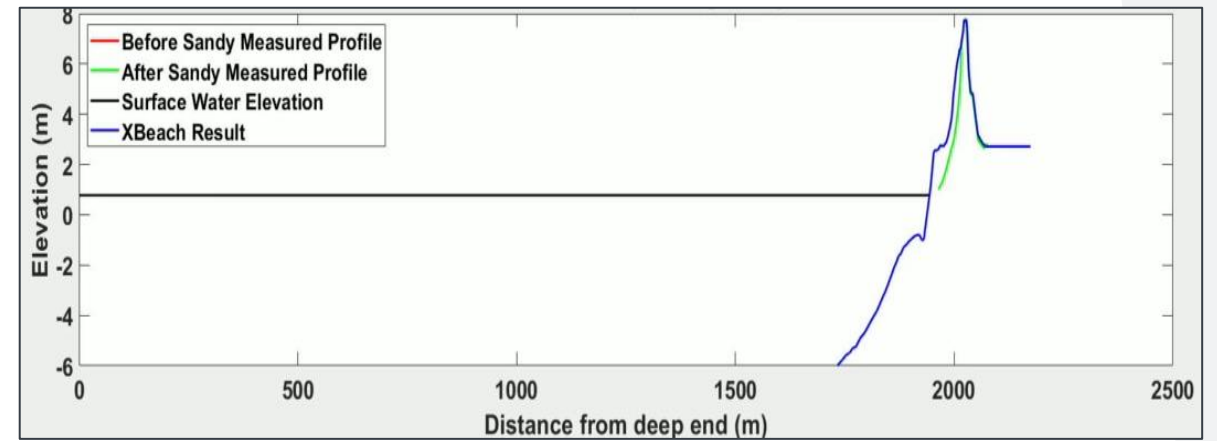
Jamous et al. (2023). npj Climate and Atmospheric Science

Projections of Future Changes: Probability of Dune Damage Classes



Jamous et al. (2023). npj Climate and Atmospheric Science

Ongoing work: Using XBeach non-hydrostatic to quantify the effect of HCC and SLR on the hurricane-induced runup and overtopping hazards.



Conclusions

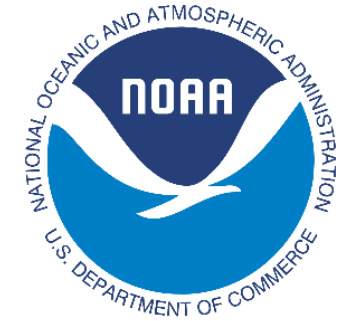
Conclusions

- The study projected the effects of climate change under a high emission scenario (RCP 8.5) on hurricane-induced waves and associated coastal erosion hazards from the historical period of 1980-2000 to the future period of 2080-2100.
- The projections of future wave heights show statistically significant increases in the wave heights induced by major hurricanes.
- The regionally averaged 100-year eroded volume metric of beach-dune systems would increase by 58 and 84 percent, respectively, under the HCC and HCC+SLR scenarios.
- The projections show a large spatial variability in future changes to erosion hazards, suggesting that, in addition to HCC and SLR, the morphological characteristics of beach-dune systems play an important role in the impacts of climate change on coastal erosion.





Thank You



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